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Effects of two types of solar wind streams on cosmic ray intensity

R S Yadav, Badruddin* and N K Sharma

Cosmic Rays and Space Physics Group, Department of Physics, Aligarh Muslim University, Aligarh-202 002, India

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Abstract : Influence of two types of high speed solar wind streams (HSS)— coronal hole and solar flare associated— on cosmic ray intensity, recorded by three neutron monitors, has been studied for the period 1972-84. This study was also carried out separately for periods before and after the solar field reversal of 1980. Cosmic ray intensity depressions due to the flare-associated streams are Forbush-like and much larger in magnitude than the depressions associated with the coronal hole streams This difference between the depressions may be due to the reason that the magnetic field is more turbulent during the flare-associated streams than the hole-related streams. It is also obseved that the spectral index of the events is insensitive to the field reversal in 1980.

Keywords : Cosmic ray intensity, solar wind streams

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1. Introduction

Galactic cosmic rays (CR) observed at earth have been affected by the magnetic inhomogeneities during its passage through the heliosphere and thus it is modulated by the conditions of the interplanetary medium. Thus the understanding of the modulation process can be used for diagonising the interplanetary conditions by studying the variations in cosmic ray intensity. It is well known that the interaction between the interplanetary magnetic field (IMF) and the cosmic rays is the basic and the common cause of all CR modulations with different time-scales [1]. Thus the investigation of one effect will help in understanding of

*S. P. D. College, Shohratgarh, Siddharth Nager, India

modulation with other time scales. Thus the study of short-term CR intensity variations has an important role to understand the solar cycle modulation [2].

The high speed solar wind streams (HSS) lasting for several days have been observed by setellite and space crafts. These streams produces geomagnetic disturbances and change in the level of cosmic ray intensity. Thus, these streams are the key-link in the complex chain of events that link geomagnetic activity/cosmic ray intensity to solar activity and their study therefore, is of great interest to solar-terrestrial and cosmic ray physics community [3-6].

The HSS streams are associated with the solar active regions and coronal holes, which themselves have different features. Coronal holes are regions of low density and temperature and occur in weak, open, diversing unipolar regions [7], whereas active regions show a complex magnetic structure including closed field zones and evolve rapidly when for example, energetic solar flares occur in such regions. Thus, it is expected that the interplanetary parameters during the periods of these HSS-streams (associated with flares and coronal holes) will be remarkably different and therefore, it is important to see the response of cosmic rays to these two types of HSS streams, whether it is different or same [5,6,8,9].

Another solar phenomenon of interest in cosmic ray research is the general magnetic field of the sun, observed most clearly in polar regions, which reverses its polarity near every sunspot maximum, going through a cycle of 22-years. It is therefore, of considerable interest to see whether the diminution in short-term cosmic ray intensity show any change in spectral characteristics, as a result of the solar polar field reversal.

2. Data analysis

The detail study of the effects of two types of HSS streams (coronal hole and flare-associated) on cosmic rays, observed by three neutron monitors, has been done for the period 1972-84. In the analysis, the pressure-corrected cosmic ray intensity data recorded by monitors at Deep-River (cut of rigidity, Rc = 1.02 GV), Rome (Rc = 6.24 GV) and Mt. Norikura (Rc = 11.36 GV) have been used. Superposed epoch analysis of these data has been performed. In this analysis, the arrival day (on earth) of the HSS-streams has been taken as the epoch (zero) day.

Total 395 HSS streams have been selected and divided into two groups, stream associated with coronal holes (273 streams) and streams related to solar flares (122 streams).

This analysis was also done during the periods of two states of solar magnetic polarity *i.e.* 1972-79 (60 streams) and 1981-84 (42 streams) as the polarity reversed in 1980.

The effect of increase in IMF strength and wind speed observed during individual flare-associated HSS streams on cosmic ray intensity, has also been studied. For this purpose, individual Forbush like CR decreases (amplitude ≥ 1.5% at Deep-River) due to flare associated streams have been selected and their decrease amplitude (in percent) has been plotted against the increase in IMF strength and solar wind speed.

3. Results and discussion

Figure 1 shows that the depression in CR intensity, due to streams from coronal holes, starts slowly on the arrival of the stream at the earth (zero day), it remains depressed for a few days

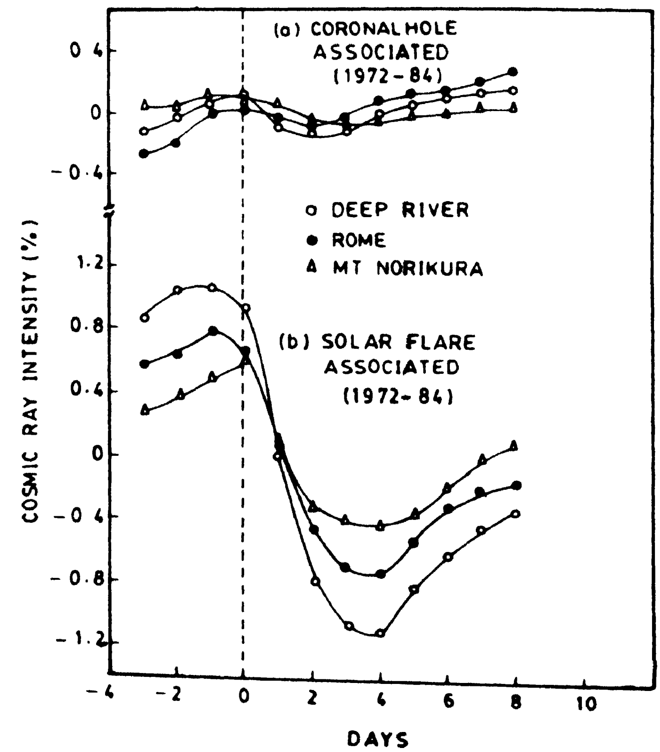

Figure 1. Superposed epoch results of cosmic ray intensity (in percent) The epoch day corresponds to the arrival day of high speed solar wind streams associated with coronal holes (Fig 1a) and solar flares (Fig.1b) during 1972–84

before recovering slowly to pre-decrease level. However, on the arrival of flare related streams, CR intensity decreases sharply and the recovery takes places slowly, *i.e.* the decrease in this case is Forbush-type. The amplitude of diminution in the latter case (Figure 1b) is much higher than that in former case (Figure 1a) inspite of the fact that the average solar wind speed and the mean IMF strength is almost same in two cases (Table 1) [5,6,10]. Our results are in agreement with the results reported earliers [6,8,11,12]. Though the observations are quite successful in identifying the solar causes of cosmic ray intensity diminution, there has not been much efforts to ascertain the possible mechanism responsible for distinct intensity time profiles observed due to streams of differents solar origin.

The large difference in the amplitude and time-profile associated with cosmic ray diminution (Table 1, and Figure 1a,b) may be because of other parameters associated with cosmic ray modulations *e.g.* small scale fluctuations in the magnetic field.This conclusion may also be drawn from Figures 2 and 3 in which change in cosmic ray intensity decrease (in percent) versus change in magnetic field and change in solar wind speed associated with individual flare-generated streams is plotted. The correlation between CR intensity decrease

Table 1. Comparision of decrease in cosmic ray intensity with average solar wind parameters dunng two types of streams.

Stream type	Cosmic ray decrease (%) at			Average field (γ)	Average velocity (km/sec)
	Deep River	Rome	Mt Nonkura		
Flare-associated	2.18	1 55	1 04	17	643
Coronal hole associated	0.26	0.06	0 08	16	636

and change in two interplanetary parameters is poor (Figures 2 and 3). This poor correlation may be because, as mentioned earlier, other parameters *e.g.* magnetic field fluctuations are also associated with such modulations/decreases.

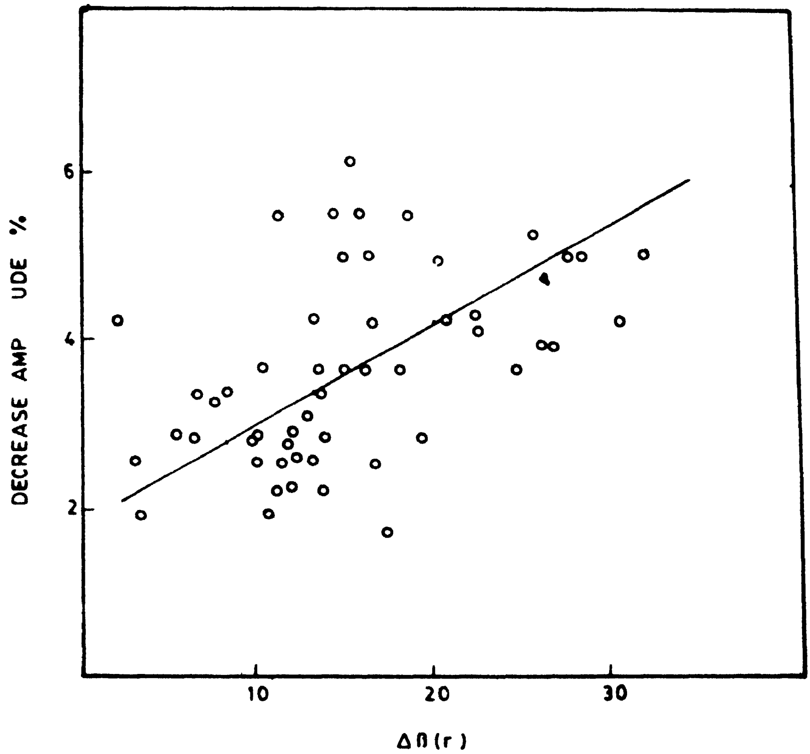

Figure 2. Correlation diagram between change in field magnitude (ΔB) and change in cosmic ray intensity (%) during flare-associated high speed streams. The straight line is the least square fit to the data.

The work of earlier workers [13-15] have created considerable interest and their suggestions that modulation of cosmic ray intensity should have a significant component controlled by the state/polarity of IMF as transported out from the sun and hence should have a solar magnetic cycle effect on the drift of cosmic rays in the heliosphere. But supportive and

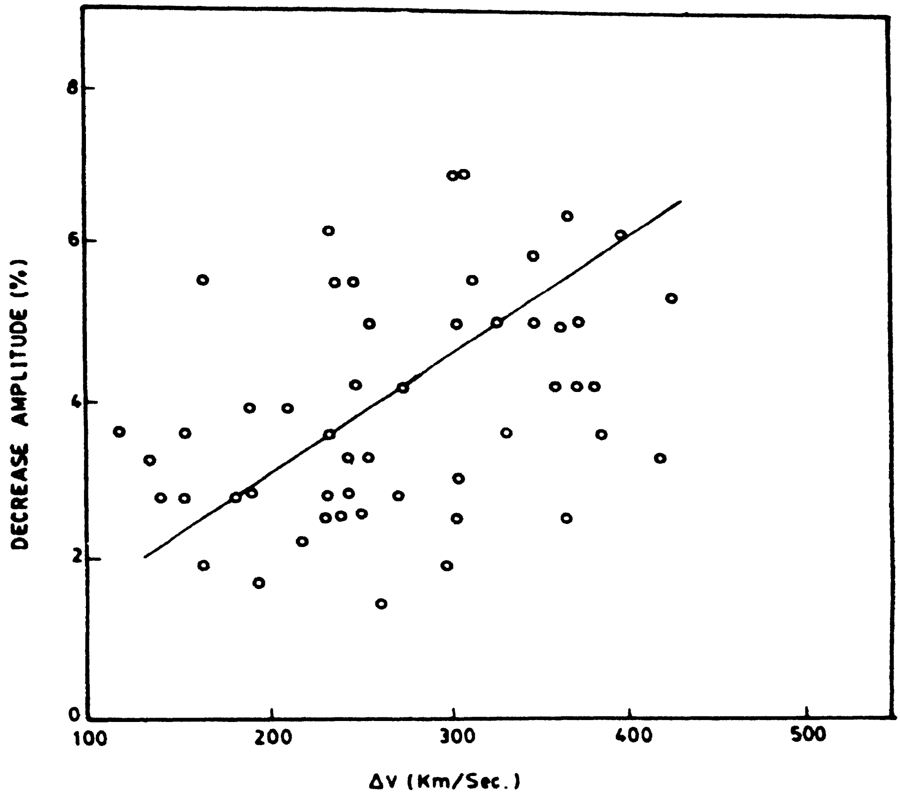

Figure 3. Correlation diagram between change in solar wind velocity (ΔV) (km/sec) and change in cosmic ray intensity (%) during flare associated high speed streams. The straight line is the least square fit to the data.

unsupportive experimental evidences to this concept are reported in the literature [16]. Thus, to look the effect of solar polar magnetic field polarity on the rigidity spectrum of short-term intensity decreases, we have divided our period of study (1978-84) into two groups *viz.* 1972-79 and 1981-84 (polarity reversed in 1980). Figure 4 shows that superposed epoch results of cosmic ray intensity with respect to flare-generated HSS streams observed during 1972-79 (Figure 4a) and 1981-84 (Figure 4b).

We fit the rigidity spectrum for two periods of different solar magnetic polarity, with a power law R and found that values are almost same in both the polarity states of the magnetic field (γ = 0.79 and 0.84) for 1972-79 and 1981-84 respectively. It shows that the solar magnetic field polarity (or field reversal of 1980) has no marked effect on the rigidity spectrum of the CR intensity decreases or such modulations. Without including drifts, the simulation results of Nishida [17] and Kadokura and Nishida [18] also predicts γ = 0.8 for both the polarity states, but our results are not in agreement with the two-dimensional numerical model incorporating drift effects [17], which predict a softer rigidity spectrum (γ = 0.66) for 1972-79 and (γ = 0.54) for 1981-84, when drift effects were taken into account.

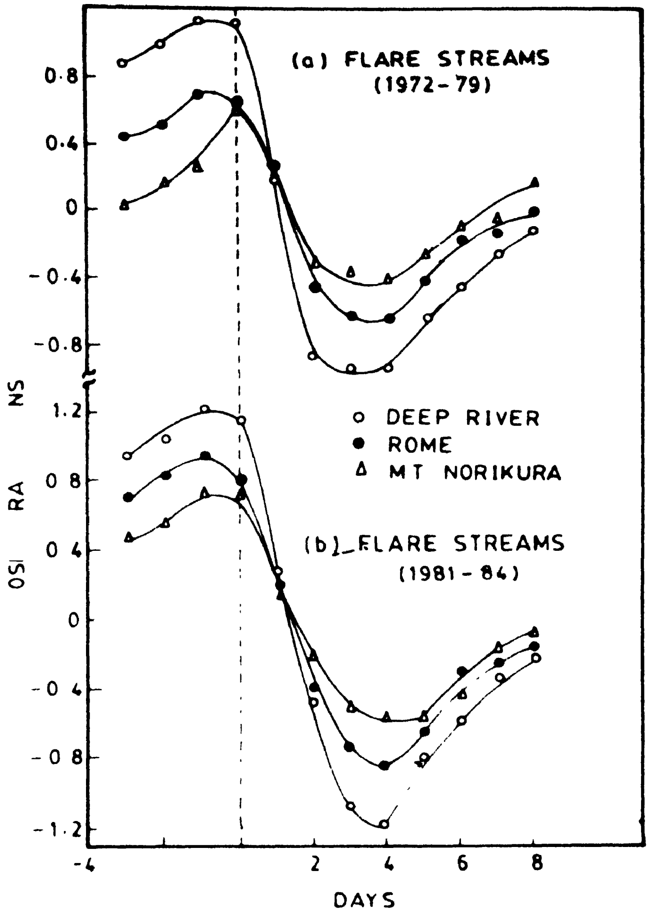

Figure 4. Superposed epoch results of cosmic ray intensity (in percent). The epoch day corresponds to the arrival day of flare-associated high speed streams during 1972–79 (Fig 4a) and 1981–84 (Fig. 4b)

Several authors [19-22] have studied the properties of Forbush like decreases on the polarity of the solar magnetic field days and contradictory results have been obtained. Thus it is useful that further study of the properties of Forbush-like decreases should be done in detail, because it is apparently related with the modulation models.

Our results are not [19-22] in agreement with the predictions, but regarding rigidity spectrum do support Kadokura and Nishida's model without considering drift effects.

The reason for the lack of observational support to the predictions of drift models of Forbush-decreases may be because during such decreases the interplanetary field fluctuations are turbulent enough and not conducive to drifts.

4. Conclusions

1. The decrease in CR intensity due to high speed streams (HSS) from solar flares is much larger (and Forbush type) than due to streams from coronal holes. The reason for this difference may be that during flare related streams the fluctuations in the magnitude/or direction of the interplanetary magnetic field are more/large than coronal hole-related streams.
2. The rigidity spectrum of transient CR intensity-decreases related to flare-generated streams is not solar polarity dependent and the spectral index (γ) is insensitive to field reversal and does not agree with the results predicted by drift models.
3. The studies of effects of different solar streams on cosmic ray intensity profile may be useful in deciding the origin of these streams and also in deciding the controversy regarding the cause of all major geomagnetic storms (both recurrent and non-recurrent).

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